

Research Article

Influence of Hot Metal Flow State to the Hearth Flow Field during Blast Furnace Tapping

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Abstract: Blast furnace tapping is one of the most important aspects of BF iron-making, a process during which the ideal state is for the molten iron to remain the invariant and the level of liquid to remain stable. However, due to the viscosity of molten iron, the liquid level will tilt to one side near the tap-hole, causing the iron flow field during blast furnace tapping to change with time. This research simulated two cases of horizontal and inclined molten iron liquid levels in the process of blast furnace tapping. This study also discusses different hearth erosion situations and explains the rationality of blast furnace large-scale trends from the perspective of molten iron liquid level stability.

Keywords: Blast furnace, hearth flow field, hot metal, tilt angle

INTRODUCTION

The life of a blast furnace is an important factor affecting the cost of production. Damage to a blast furnace caused by erosion directly influences the life of the hearth and blast furnace erosion has a bearing on the hot metal flow state (Xu, 2001). Due to molten iron viscosity, the liquid level will tilt to one side near the tap-hole, causing the iron flow field to change over time during blast furnace tapping.

The state of molten iron flow on the blast furnace hearth and erosion conditions caused by the inclination of the iron plane during blast furnace tapping is important to the relationship between furnace cylinder size and hearth life. In recent years, the development of computer systems and numerical simulation software has been continuously improved. Previous studies have developed hearth flow field numerical simulation research, including CFD simulation of the iron flow field of blast furnaces (Iwamasa *et al.*, 1997), mathematical models considering the heat flow path and heat flow area to evaluate hearth erosion (Jin-Su *et al.*, 1999), CFD simulation of the flow state of hearth molten iron and determination of the relationship between molten iron flow state and the shape and porosity of dead stock and the depth of the hearth (Sun, 2005) and mathematical models of the erosion on the blast furnace hearth and bottom using two-dimensional heat transfer equation as the starting point (Du and Chen, 1997). In addition, through the simulation of hearth heat transfer, flow field and shear stress, the shear stress of hot metal to the hearth wall decreased as the volume of the molten iron layer at the bottom (dead man) increased and there was a minimum (Bhavin *et al.*, 2006; Chen-En *et al.*, 2008). While the above

studies comprehensively discuss the impacts of molten iron flow, research regarding the degree of hearth erosion caused by the tilt angle of the molten iron liquid level is still lacking.

The present research used numerical simulation software CFX. We simulated molten iron at different level obliquity of the hearth during blast furnace tapping, obtained blast furnace hearth's visualization results of molten iron flow during blast furnace tapping and analyzed different periods of change for molten iron flow in the blast furnace hearth during blast furnace tapping.

MODELING

In this study, according to actual blast furnace hearth geometric parameters, a 1:1 3D geometry drawing of the hearth was created using Icem CFD software and make meshing on it. To ensure the accuracy of the calculations, set reasonable mesh size, adjacent mesh units does not exceed 1.5 times as large as the unit and for all the generated mesh, the mesh quality should be at least 0.3; to ensure the calculation speed, the mesh unit quantity control at around 1 million. The result of mesh division is shown in Fig. 1.

On the basis of a physical model, we determined the mathematical model for the flow field of hot metal for blast furnace hearths. The application of mathematical simulation models included basic equations of fluid flow, an expanded mathematical model of hot metal flow fields for blast furnace hearths, a two-equation model of turbulent flow, a fixed bed flow mathematical model based on structural features of the hearth and wall function method to calculate the near-wall fluid flow near the hearth wall. The

NUMERICAL SIMULATION OF HOT METAL FLOW IN BLAST FURNACE HEARTH WITH HORIZONTAL HOT METAL LEVEL DURING BLAST FURNACE TAPPING

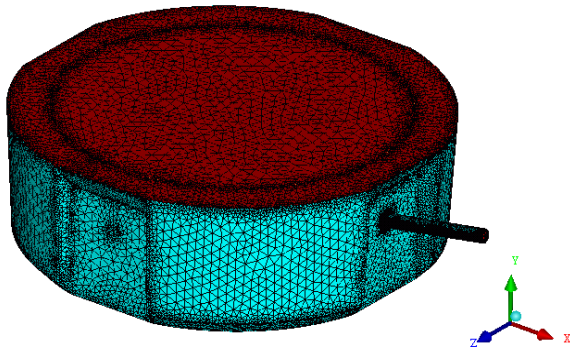


Fig. 1: Mesh division

Suppose hot metal level is horizontal in the process of blast furnace tapping and with tapping, the liquid level drops. The selected heights of the liquid iron were 4.3 m, 4 m and 3.7 m to simulate the flow state of the hearth. We cut out longitudinal sections of the tap-hole and intersecting surfaces at depths of 0.5 m, 2.3 m and 3.2 m from the hearth bottom. Simulation results are shown in Table 1 and 2.

From analysis of the simulation results, the following conclusions were reached:

simulation boundary and initial conditions were based on actual blast furnace production, set space entrances and exits. And wall parameters. Select the initial and boundary condition parameters and the necessary mathematical model to define CFX-Pre, then open CFX-Solver to calculate the model and last CFX-Post can output visualization of simulation results when the calculation is completed.

- Compared with the intersecting surface of the tap-hole, the height of hot metal level was 4.3 m, the hot metal flow velocity increased in large scope around the tap-hole and the hearth wall near tap-hole was washed seriously. These findings resulted from the increasing height of the hot metal level, which increased the potential energy of the hot

Table 1: Molten iron flow rate in blast furnace hearth at different heights

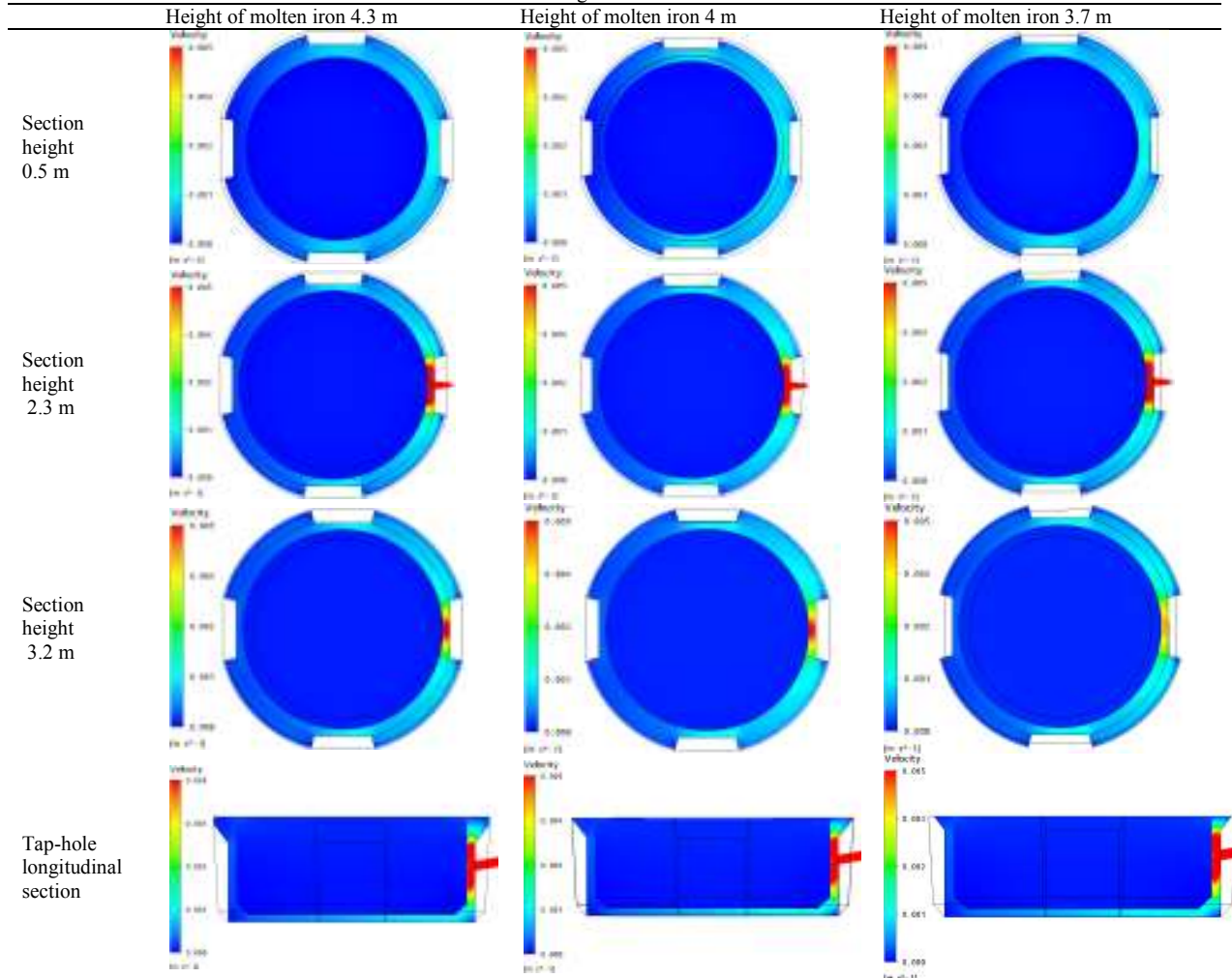
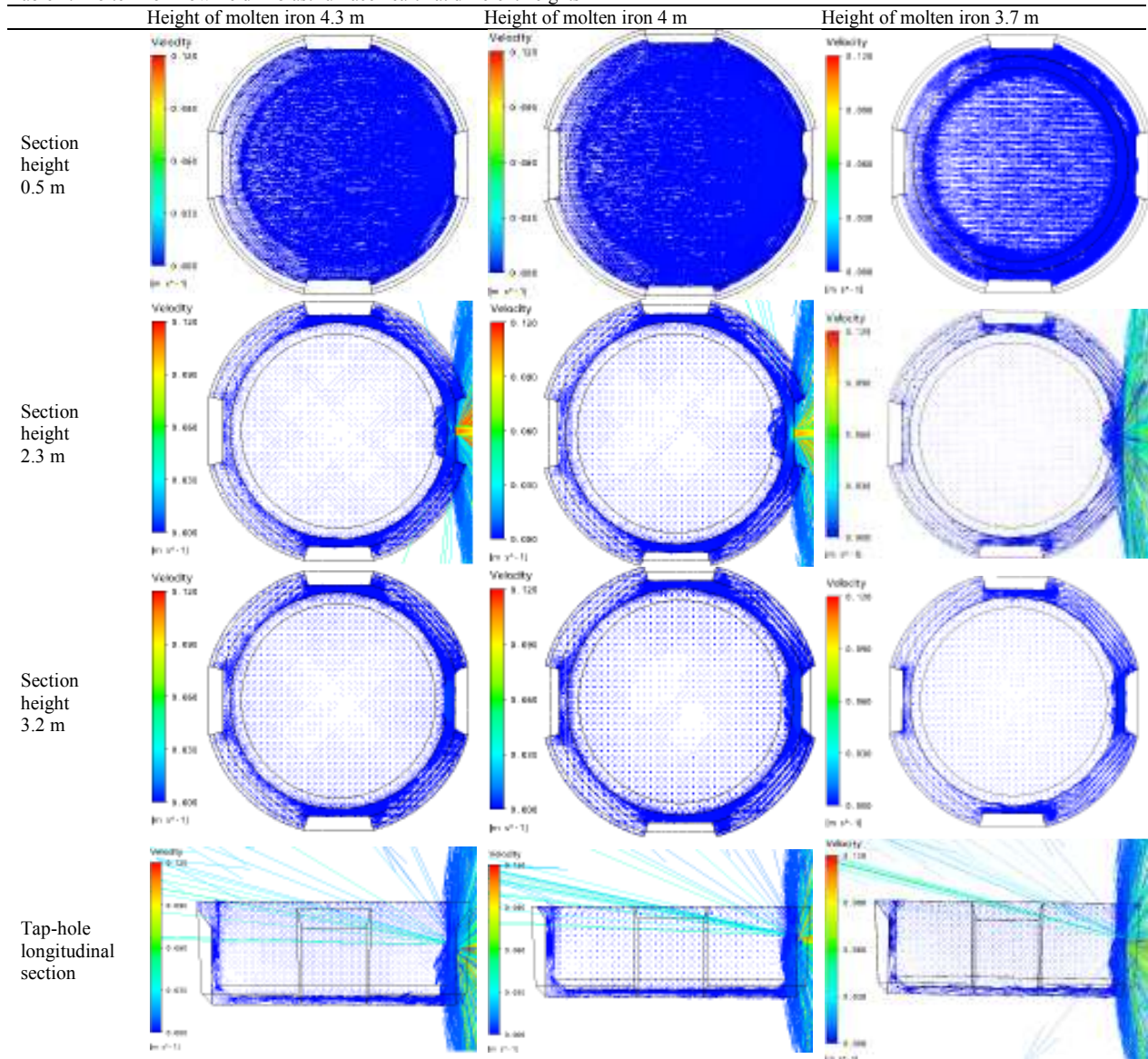


Table 2: Molten iron flow field in blast furnace hearth at different heights



metal flowing to the tap-hole and increased flow velocity;

- In contrast to 3.2 m cross section, as liquid iron depth reduced, the flow speed of molten iron at the top of tap-hole reduced, when the height of liquid iron was reduced, severe erosion to the wall near the tap-hole was also reduced;
- From the flow field figure, with the reduction in liquid iron height, the tap-hole of molten iron speed lowered and tap-hole erosion was also reduced. During the process of tapping, the potential of liquid iron was initially great, the speed of liquid iron flow to the tap-hole was fast and erosion to the tap-hole was significant. As the tapping process continued, the liquid iron level decreased, liquid iron flow-speed on the hearth and around the tap-hole was reduced and erosion to the tap-hole and

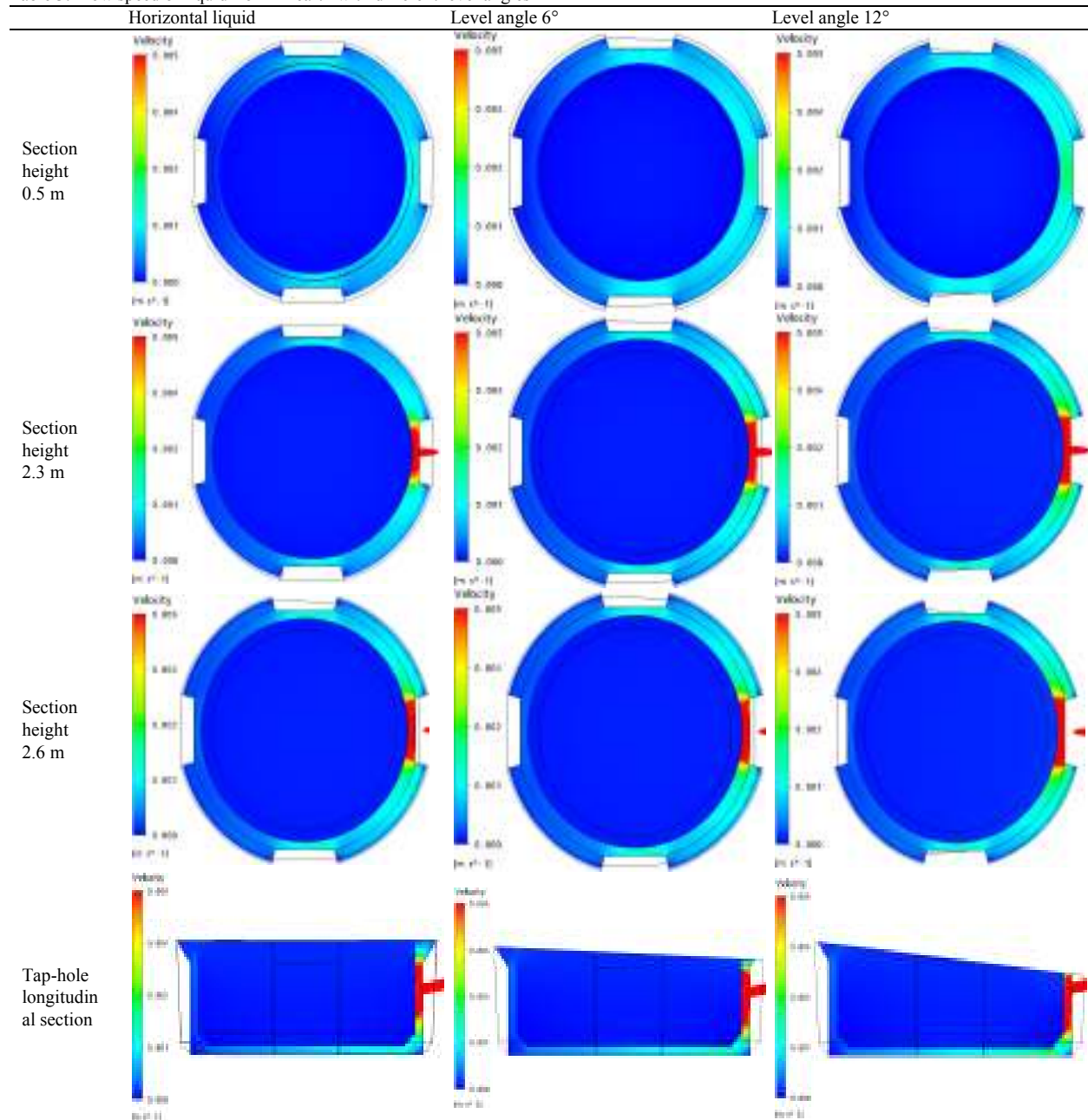
hearth was also reduced. Thus, for the level of liquid iron to be maintained, a reasonable height range was required to reduce the erosion of the hearth and tap-hole.

FLOW FIELD SIMULATION OF HEARTH WHEN THE LIQUID IRON LEVEL TILTED DURING TAPPING

Due to the viscous effects of the liquid iron in the hearth, the surface does not remain horizontal during tapping, but tilts in the direction of tap-hole. At different time during tapping, different inclination angles are observed in the liquid level.

We selected dip angles of 0°, 6° and 12° to simulate the flow state of the hearth and cut longitudinal sections of the tap-hole and intersecting

Table 3: Flow speed of liquid iron in hearth with different level angles



surfaces at a depth of 0.5 m, 2.3 m and 2.6 m from the hearth bottom. The simulation results are shown in Table 3 and 4.

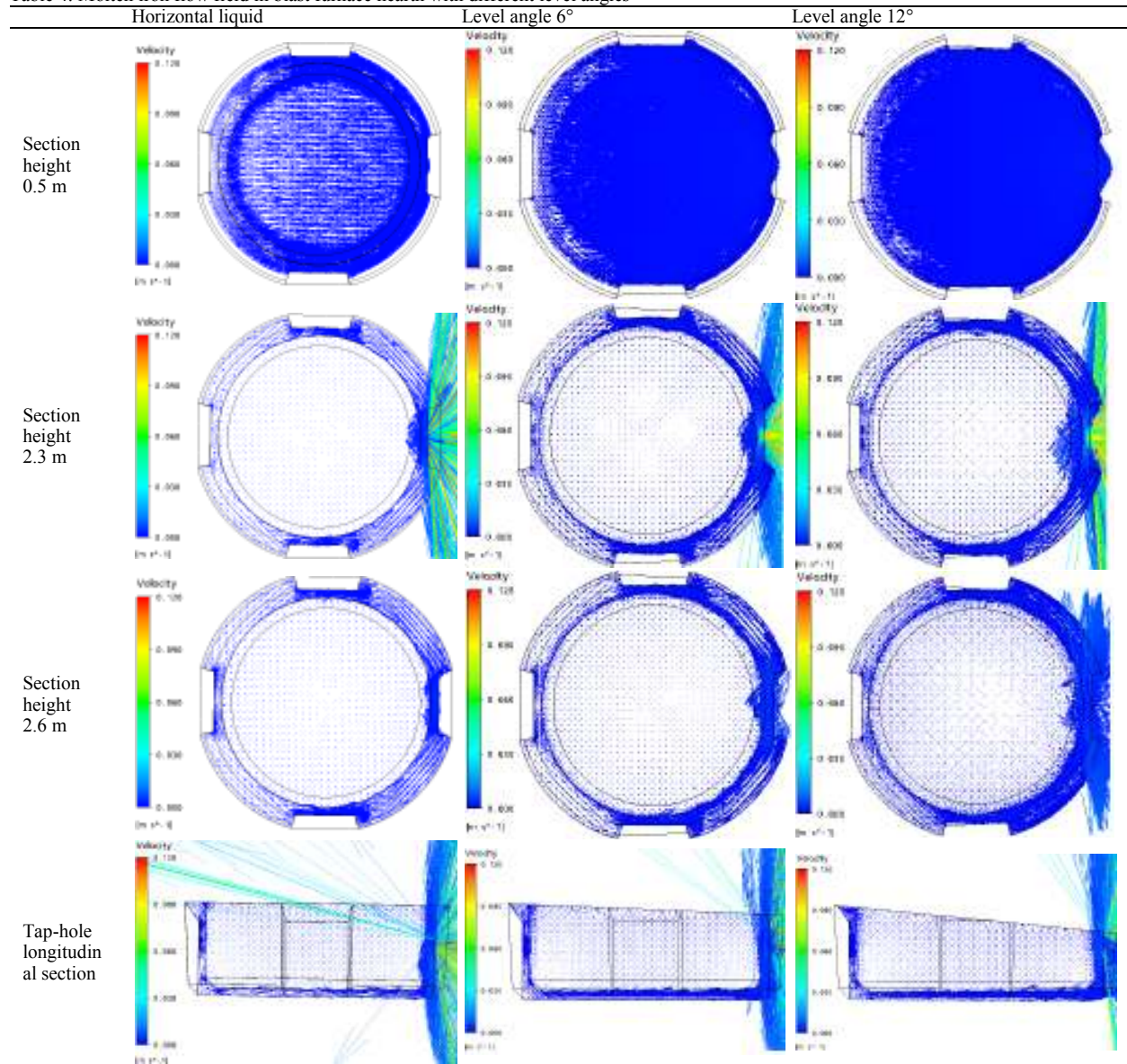
From analysis of the simulation results, we reached the following conclusions:

- When liquid iron angle increased, the flow speed of liquid iron near the hearth increased during tapping, thus produced more stress and increased erosion at the wall of the tap-hole
- Contrast 2.3 m cross section, when the liquid iron angle increased, the high speed molten steel flow area increased and thus a greater area of the furnace wall near the tap-hole experienced erosion

- From the flow field diagram, when the liquid iron level angle increased, the flow intensity of liquid iron of the hearth in the circulation area increased, the flow intensity of liquid iron near the tap-hole also increased and more serious erosion appeared in the hearth near the tap-hole

Thus it can be seen, with tapping and viscosity, height differences appeared between areas far and close from the tap-hole. Thus, potential energy differences appeared; when the potential energy increased, the speed of liquid iron flow to the tap-hole increased, causing serious erosion at the tap-hole by liquid iron.

Table 4: Molten iron flow field in blast furnace hearth with different level angles



CONCLUSION

Due to the viscosity of hot metal, the level of liquid iron in the hearth will not always remain horizontal. From the study simulation of two situations in which the liquid iron level was horizontal and inclined, we concluded the following:

- Molten iron above the tap-hole was gradually reduced as tapping continued, the pressure effect declined and the speed of tapping decreased
- When the liquid surface tilted during the tapping process, the gravitational potential energy of the hot metal in the space far from the side of tap-hole sides was larger and the trend flowing towards the tap-hole was stronger. Thus, the erosion to the

hearth and space around the tap-hole by hot metal under was more serious

- Maintaining a horizontal level during tapping helped reduce erosion to the tap-hole, maintain a more stable liquid level of large blast furnaces and reduced the occurrence of obviously tilted liquid. The simulation results also explained the rationality for the development tendency of large blast furnace from the side of stabilizing hot metal surface

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